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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

Many studies of sea lice biology, monitoring, control and management exist, which must be consolidated to provide managers with peer reviewed, robust science advice.

Fisheries and Oceans Canada's (DFO) Aquaculture Management Directorate requested peer-reviewed science advice to support the optimization of sea lice management by non-chemical methods, including the development of integrated pest management, mitigation strategies and science-based conditions of license. This advice is required to support management decisions on issues such as thresholds/triggers, effective monitoring protocols and wild/cultured interactions related to sea lice. It is recognized that there are biophysical differences between salmon growing regions within Canada including species of sea lice, alternate hosts, oceanography, etc. These differences would also need to be considered when applying this science advice.

On September 25th to 27th, 2012, Fisheries and Oceans Canada (DFO) held a National Peer Review Process, in Ottawa, to develop scientific advice on the above questions. The meeting reviewed six working papers concerning the biological aspects, monitoring and non-chemical management practices of sea lice. There were 43 participants at the meeting and 5 joined by teleconference. Attendance (Appendix 1) spanned government, academia, industry and environmental non-governmental organizations. The Terms of Reference for the meeting, developed by a Steering Committee, are included at the end of this report (Appendix 2).

The Terms of Reference addressed ten objectives under three main groupings:

1. Population ecology and epidemiology of sea lice in Canadian waters,
2. Monitoring for sea lice on farmed and wild salmon in western and eastern Canada, and
3. Non-Chemical Measures for control and prevention.

Each of the working papers focussed on various aspects of these three areas. One purpose of the peer review was to assess whether the conclusions presented in the review papers were scientifically robust and a fair summary of the current state of knowledge for the issues specified in the Terms of Reference.

The six working papers were circulated to meeting participants prior to the meeting. Each paper was formally reviewed by two expert reviewers who were asked to provide their reviews on the working document at the meeting, prior to an open discussion period.

Following discussion of the review papers, the meeting moved to a discussion of conclusions and advice relative to the Terms of Reference, to be summarised in a Science Advisory Report.

SOMMAIRE

Il existe de nombreuses études sur la biologie, la surveillance, le contrôle et la gestion du pou du poisson qui doivent être consolidées afin de fournir aux gestionnaires un avis scientifique fiable et examiné par les pairs.

La Direction générale de la gestion de l'aquaculture de Pêches et Océans Canada (MPO) a sollicité un avis scientifique évalué par les pairs afin d'appuyer l'optimisation de la gestion du pou du poisson de par l'utilisation de méthodes non chimiques, y compris l'élaboration d'une lutte antiparasitaire intégrée, de stratégies d'atténuation et des conditions de permis fondées sur la science. Cet avis est nécessaire pour appuyer les décisions de gestion concernant des questions telles que les seuils et les éléments déclencheurs, les protocoles de surveillance efficaces et l'effet du pou du poisson sur les interactions entre les poissons sauvages et d'élevage. Il est reconnu que des différences biophysiques existent entre les régions salmonicoles du Canada, y compris les espèces de pou du poisson, les hôtes intermédiaires, l'océanographie, etc. Ces différences devront également être prises en compte dans l'application de cet avis scientifique.

Du 25 au 27 septembre 2012, le MPO a tenu un processus national d'examen par les pairs, à Ottawa, afin d'élaborer un avis scientifique relatif aux questions susmentionnées. La réunion a permis d'examiner six documents de travail concernant les aspects biologiques, la surveillance et les pratiques de gestion non chimiques du pou du poisson. Quarante-trois personnes ont participé à la réunion et cinq se sont jointes par téléconférence. Les participants (annexe 1) provenaient du gouvernement, du milieu universitaire, de l'industrie et d'organisations environnementales non gouvernementales. Le cadre de référence pour la réunion, élaboré par un comité directeur, est inclus à la fin du présent rapport (annexe 2).

Le cadre de référence aborde dix objectifs répartis en trois groupes principaux :

1. Épidémiologie et écologie des populations de pou du poisson dans les eaux canadiennes;
2. Surveillance du pou du poisson sur le saumon d'élevage et le saumon sauvage dans l'Ouest et l'Est du Canada;
3. Mesures non chimiques de contrôle et prévention.

Chacun des documents de travail était axé sur divers aspects de ces trois points. Le but de l'examen par les pairs consistait à évaluer si les conclusions présentées dans les documents examinés étaient rigoureuses sur le plan scientifique et constituaient un résumé juste de l'état actuel des connaissances relatives aux questions précisées dans le cadre de référence.

Les six documents de travail ont été remis aux participants avant la réunion. Chaque document a été officiellement examiné par deux experts à qui l'on a demandé de présenter leur examen du document de travail à la réunion, avant une période de discussion ouverte.

Après les discussions sur les documents examinés, les participants ont tenu une discussion sur les conclusions et les avis liés au cadre de référence qui devront être résumés dans un avis scientifique.

INTRODUCTION

WELCOME

The meeting Co-chairs, Howard Powles and Jay Parsons, welcomed participants (Appendix 1) to the meeting. Darlene Smith provided a brief overview of Fisheries and Oceans Canada's (DFO) Science Advisory Process. Jay Parsons reviewed the Terms of Reference for the meeting and explained the process for peer review and discussions.

A total of six working papers had been prepared for the meeting by selected experts. For each paper, the lead author summarised the main points of the paper, highlighting the state of knowledge of the subject area and identifying knowledge gaps and research needs. The author's presentation was followed by comments from the peer reviewers. The floor was then opened to participants for questions and discussions before finalizing comments on the paper.

BACKGROUND

The Aquaculture Management Directorate of DFO requested science advice to support the optimization of sea lice management, including the development of integrated pest management, mitigation strategies and science-based conditions of license. The Terms of Reference (TOR), setting out the scope of this advice, were developed by a Steering Committee consisting of members with sea lice expertise, spanning government, academia, industry and environmental non-government organizations.

The TOR summarised what would be included in a Science Advisory Report on the monitoring and non-chemical treatment methods for sea lice in Canada. The following are the objectives set out in the TORs.

Population ecology and epidemiology of sea lice in Canadian waters

1. Role of other sea lice hosts (wild salmonid and nonsalmonid) as reservoirs and other factors influencing sea lice dynamics near or on farms.
2. Scientific basis for setting management and regulatory thresholds to treat farm salmon and minimize the risk of harm to wild juvenile salmon from exposure to farm-source sea lice.

Monitoring for sea lice on farmed and wild salmon in western and eastern Canada and advice on sound methodologies

3. Sampling design protocols for on-farm lice monitoring, including: number of fish to be sampled, identification of lice, number of samples, handling of fish, etc.
4. Program design for on-farm lice monitoring, including: frequency of sampling, timing, environmental factors to be considered, sea lice dynamics, etc.
5. Sampling design protocol for wild fish lice monitoring, including: number of fish to be sampled, identification of lice, number of samples, handling of fish, background sea lice levels, etc.
6. Program design for wild fish lice monitoring, including: frequency of sampling, outmigrations, in-migrations, sampling location, timing, environmental factors to be considered, sea lice dynamics, and other considerations (e.g., species differences, at-risk status of wild stocks of interest), etc.
7. Protocols for the management, dissemination and analysis of data resulting from monitoring programs.

Non-chemical measures of control, and prevention

8. Scientific advice on factors that influence the effectiveness of fallowing as a means of sea lice control, including fallowing time required, scale of fallow (e.g., farm-scale versus bay-scale), other factors required to interrupt sea lice population dynamics on farms to decrease next year's load, etc.

9. The effect of farm density and stocking density on sea lice population dynamics at different scales (i.e., individual pens, individual farms, within a bay or area).

10. Scientific evidence to the effectiveness of other means of sea lice control such as, but not limited to, sea lice traps, cleaner fish, Integrated Multi-Trophic Aquaculture (biological filtering), etc.

Each of these objectives was addressed through working papers prepared by experts in the related fields of research. These were the papers which provided the basis for discussion at this meeting.

The first two days of the meeting (September 25th and 26th) were spent by the group reviewing the working papers. The final day (September 27th) was dedicated to the development of a draft Science Advisory Report.

WORKING PAPER A.
BIOLOGY OF *LEPEOPHTHEIRUS SALMONIS* & *CALIGUS* SPP. IN WESTERN AND EASTERN CANADA

PRESENTATION HIGHLIGHTS

Presenter: S. Jones, Co-author (Authors: S. Jones and S.Johnson)

This paper provided an overview of the biology of the principal species of sea lice found in Canada, including life cycle, geographic variation, reproductive biology, effects of temperature and salinity on development, sensory adaptations and host factors. Emphasis was placed on those aspects of sea lice biology particularly amenable to control measures.

Key summary points from the presentation included:

- Two genera of sea lice are of particular importance – Lepeophtheirus, including Lepeophteirus salmonis, found on both Atlantic and Pacific coasts, and Caligus of which specific species are found on Atlantic and Pacific coasts
- Genetic differences exist between Atlantic and Pacific populations of L. salmonis, and these may represent different species
- More is known of the biology of L. salmonis, and its impacts are greater, although Caligus spp may be more abundant in the wild
- The biology of sea lice is broadly divisible into free-living and parasitic phases
- Environmental salinity and temperature regulate development rates and survival in both phases
- Free living stages have numerous adaptations that can respond to recognise physical and chemical environmental gradients and behavioural responses are elicited to optimise host finding and settlement
- Sea lice that are parasitic on farmed (Atlantic) salmon in Canada also have a range of natural hosts
- A wide range of susceptibilities to L. salmonis occurs among salmon species and strains, particularly in juvenile salmonids

- Infections tend to be of reduced duration and lower intensity on less susceptible species

Suggestions for future research areas were indicated as follows:

For L. salmonis

- Improve knowledge of the differences between Atlantic and Pacific Ocean L. salmonis varieties
- Thermal and salinity gradients – the effect of salinity and thermal gradients on development and movements of infective stages
- Virulence – the relation of sea lice infestation levels to fish health more generally
- Viability of egg strings under sub-optimal temperatures
- Compare affinity of copepodids to commercially and ecologically significant fish species (e.g. salmon, sticklebacks)

For Caligus spp.

- Effects of temperature and salinity on development, survival and infectivity (both coasts)
- Reproductive output of Caligus spp. under various host / environmental conditions (both coasts)
- Relative importance of the copepodid, pre-adult and adult stages in establishing infections on salmonids (both coasts)
- Why do Caligus spp. tend to have broader host ranges than L. salmonis? (both coasts)
- Compare effects on hosts of Caligus vs Lepeophtheirus spp. (both coasts)

PEER-REVIEWER HIGHLIGHTS & GENERAL DISCUSSION HIGHLIGHTS

(Reviewers: K. Kroon Boxaspen and M. Beattie)

K. Kroon Boxaspen's review (Appendix 4) was read into record by Jay Parsons, while Mike Beattie presented his review at the meeting. There were only positive, supportive comments by reviewers and meeting participants, for this paper. Little discussion was held on required improvements to the paper, other than to suggest that it could be linked to the other working papers, particularly concerning oceanography effects on sea lice (Working Paper B) and that the references section might be extended.

Points from general discussion included:

- A distinction must be made between "infection" (for example by sea lice) and "disease", and the impact of sea lice in a general context of fish health needs to be better defined.
- The species of sea lice which is most important on farms may vary with location and time.
- The importance of defining the life stage which is most important for control purposes was emphasised; in general the infective mobile stages are probably most important for control.

WORKING PAPER B.
OCEANOGRAPHIC CONDITIONS OF SALMON FARMING AREAS WITH ATTENTION TO THOSE FACTORS THAT MAY INFLUENCE THE BIOLOGY/ECOLOGY OF SEA LICE AND THEIR CONTROL

PRESENTATION HIGHLIGHTS

Presenter: K. Brewer-Dalton, Co-author (Authors: F. Page, P. Chandler, A. Ratsimandresy, K. Brewer-Dalton, Contributing Authors: B. Chang, S. Scouten and N. O'Brien)

This paper focused on the oceanographic factors that affect sea lice dispersal and reproduction – salinity, temperature, currents, and water column stratification. It also outlined oceanographic conditions in the major salmon farming regions in the country - British Columbia (BC), New Brunswick (NB), Nova Scotia (NS), and Newfoundland (NL) - which might influence the biology and ecology of sea lice.

Key summary points from this presentation included:

Temperature:

- Seasonal cycle varies with area, but both coasts have higher temperatures in the summer and lower in the winter.
- Mean minimum temperatures are lower, and mean maximum temperatures are higher, on the Atlantic coast than on the Pacific coast.
- Temperature data are collected from many stations throughout inlets and bays, but are generally not available at site level.
- Site level data would complement what is already being collected and potentially refine models.

Salinity:

- BC and NL generally have more freshwater influence than NS and NB, where salinity rarely falls below 28 psu.
- Seasonal cycles vary with area.

Stratification:

- BC and NL have a mixed surface layer ranging from 5 – 15 m depth.
- Bay of Fundy in NB is less stratified than BC and NL; however, NS tends to be more strongly stratified. Mixed layer depths are at approximately 5 m.
- Stratification can have potentially significant implications for control and management, especially with respect to the use of therapeutants.

Currents:

- Tides, winds and prevailing currents affect currents in farming areas, and the current regime may be quite complex in any given area. Storm events may create currents inconsistent with the general local current regime.
- The data on currents should be collected at the site level.
  - This will validate if the models are correct.
  - This will determine if the estimates of the currents in that area are correct.
- Data collected on the east coast is mainly site level whereas on the west coast it is based on wider geographical areas.

Other issues:

- Oceanographic modelling is contributing to understanding of sea lice dispersal, and model development needs to continue.
- Other factors which may be important to sea lice dynamics, such as dissolved oxygen, should be considered in future.
- A combined approach of sea lice monitoring and hydrodynamic modelling should be taken to develop an effective means to evaluate control strategies.

- Collaboration among different bodies (industries, provinces, universities, DFO) involved in sea lice control, and collecting oceanographic data, should be encouraged with the objective of enabling a quick response when implementing sea lice control measures.

PEER-REVIEWER HIGHLIGHTS

Reviewers: M.Foreman and D. Greenburg

Reviewers suggested that the paper could look further at the differences and commonalities between oceanographic conditions in the Pacific, Newfoundland and Maritimes regions and detail how this comparative assessment would be useful in developing tools, such as models, to predict and manage sea lice in each of the regions. It was also suggested that the paper could go into greater detail in comparing sea lice management strategies at the farm and at the regional level, depending on the type of environmental parameters being measured. It was noted that it would be important for the paper to highlight that other means of lice control (such as chemical) are important to the overall sea lice management strategy on a farm or for a particular region/area.

The authors responded there is much to consider in assessing the requirements for predictive modelling of sea lice. In terms of site specific measurements, for the purposes of predictive modeling, it has been shown that even when frequent measurements are taken, there is the possibility of missing a signal if these are taken only once a day. Management needs to express its requirements as clearly as possible to support appropriate data collection, and the limitations of models need to be understood, to ensure that the appropriate amount of effort is being put into data collection. For example, if the priority is managing at the farm level, there would be less of a data requirement than there would be if management is at the regional, or area level, using models.

GENERAL DISCUSSION HIGHLIGHTS

General discussion ensued around the use of oceanographic models in predicting sea lice dispersal patterns. The group expressed interest in the application of models as a management tool but cautioned about becoming dependent upon them, noting that it may be difficult to ensure that the right type of model is being used, or that the parameters being fed into the model are appropriate for predicting sea lice dispersal. There was some discussion that models might also be used to explore broader issues, such as the impacts on wild salmon or relating sea lice distribution to food (host) abundance. Considering wild fish movements within the model would make them more realistic but this would be very complicated.

Regarding farm level versus regional level models, it was noted that there should be a balance between data collected on farms and data collected regionally. Salmon cannot be farmed in an extreme environment, but data are needed from a range of environments for model development. Ultimately, the question of what is to be accomplished with model development needs to be answered. In creating regional models, caution is required in deciding what type of areas are lumped together and specific events (e.g., freshwater run-off) also need to be considered. To ensure that appropriate information goes into models, more effective coordination of data collection efforts and biological research are required. There is also a need for more work on the behaviour of sea lice under a variety of environmental conditions to generate a better understanding of their ecology, both for model development and for the broader purpose of sea lice management.

Overall, the importance of recognising local oceanographic conditions in developing models and in understanding the dynamics of sea lice was emphasised.

This discussion was followed by some general factual corrections which were noted by the authors.

WORKING PAPER C.
POPULATION ECOLOGY AND EPIDEMIOLOGY OF SEA LICE IN CANADIAN WATERS

PRESENTATION HIGHLIGHTS

Presenter: S. Jones, (Authors: S. Saksida, I. Bricknell, S. Robinson and S. Jones)

This paper summarized research on sea lice infection patterns and epidemiology observed on wild and farmed fish on the Atlantic and Pacific coasts. Emphasis was on Lepeophtheirus salmonis, the salmon louse, since the majority of research has focused on this species. Information was also provided on Caligus spp. as available. The paper also summarized the use of management thresholds.

Key summary points from this presentation included:

Sea lice hosts:

Pacific Coast

- Wild adult salmon host sea lice – generally, the longer they are in saltwater, the higher the levels of sea lice load.
    - Sea lice loads vary with species, region, and from year to year.
    - Few cases of detrimental effects of infection by sea lice have been documented.
- Farmed Atlantic salmon host sea lice – generally, the longer they are in saltwater, the higher the levels but these can be controlled by treatment, and vary with region, annually and seasonally.
    - Little to no detrimental effects have been observed on farms on the west coast.
- Non-salmonids host sea lice – regional and species differences.

Atlantic Coast

- Wild salmon populations are very small, but still can host sea lice.
- Farmed salmon host sea lice.
- Some non-salmonid species also host sea lice (*Caligus* spp).

Thresholds

- In developing thresholds, area based, rather than farm based, management may be more appropriate. Determining an "area" for development of threshold and management practices must consider:
    - Oceanographic parameters
    - Local environment
    - Populations of concern to be targeted, including migration timing
    - Total lice thresholds (i.e., for all farms in area) rather than by farm. This may reduce the number of necessary treatments (drug use).

Key unknowns

- Better understanding of epidemiology would benefit from better knowledge of the role of non-salmonid hosts, and of migratory routes of wild salmonid hosts.

PEER-REVIEWER HIGHLIGHTS

Reviewers: L. Hammel and C. Revie

Key points from peer-reviewers included:

- The authors provided a thorough overview of the scientific literature, particularly on host reservoirs and factors influencing sea lice dynamics, but the basis for setting management and regulatory thresholds for treatment was not addressed directly or adequately.
- In general, the tone of many sections, particularly early sections, was more confrontational and judgemental than it should be. An extensive set of references was given but these were not always exhaustively or 'fairly' reviewed.
- The words "infected" and "infested" were used to describe sea lice on the host. There is a need to standardise terminology.
- The entire section touched on chemical treatments but did not address them directly. These treatments should be addressed fully as a factor that affects lice dynamics. The impact of fallowing and area management on sea lice dynamics were inadequately addressed.
- There was a clear East / West imbalance in the information presented, with an emphasis on the West coast.

In summary, reviewers suggested that there may have been the opportunity for more emphasis on non-salmonids and Lepeophtheirus salmonis hosts on the East coast. There may be many situations of unexplained dynamics with respect to host interactions, which need to be acknowledged as well – giving more specific information on weaknesses and gaps in knowledge. Regarding references, it was noted that in fairness it is important to note scientific arguments in cases where opinions and findings vary. Reviewers provided specific comments on where the paper could be supported by further references or additional explanation.

The authors responded that comments and suggestions would be incorporated into the document, as deemed fit. However, on the point of the lack of East Coast information, it would be difficult to incorporate more scientific data as this is generally rare for East coast populations. There is a lack of epidemiological information regarding sea lice on the East Coast - a gap in knowledge that should be identified as a future research area focus. The authors also noted that discussion of chemotherapeutant treatments, although not the focus of the paper or review, would be covered further in general terms within this paper to provide some context on treatments used by management.

GENERAL DISCUSSION HIGHLIGHTS

There was general discussion supporting the comments of the reviewers, particularly the comment that there was significantly less information provided concerning the East Coast and that this lack of information should be indicated as a gap in knowledge and area for research. Participants provided some specific edits to the paper, as well as some additional references to consider, which the authors also took note of and would consider in revisions.

There was a recommendation that because the paper primarily addressed epidemiology of sea lice, and not ecology in much detail, ecology be removed from the title of this paper and that it be retitled as: Epidemiology of Sea Lice. It was also generally accepted that although the paper was not meant to focus on sea lice issues outside of Canada, that it might benefit from references to studies from other countries, particularly European sources, where there is some complementary information to Canadian references given the lack of East Coast information.

With respect to the de-emphasis of chemical treatments in the paper, these are indeed important in epidemiology, but another CSAS process is considering this issue, and it was important to use the time at the current meeting to address the TORs.

The discussion closed with a few key points for consideration. There is little known about how sea lice are distributed in the wild, especially regarding the population size of hosts, and about the impact of re-infestation rates in epidemiology.

WORKING PAPER D.
MONITORING FOR SEA LICE ON FARMED SALMON

PRESENTATION HIGHLIGHTS

Presenter: Dr. Mike Beattie, Co-Author (Authors: S. Saksida, D. Whelan, M. Beattie, R. Cusack, I. Keith and M. Szemerda)

This paper described monitoring, management and reporting and treatment requirements for sea lice control in British Columbia, New Brunswick, Newfoundland and Nova Scotia and identified issues and concerns with the approaches. For example, monitoring in relation to set thresholds is required in British Columbia, with publication of results, while the Decision Support System (DDS) is a third-party system set up by Atlantic Veterinary College to collect monitoring results from farms in Atlantic provinces. The authors indicated in their initial presentation that they would modify the paper to describe how an "ideal" system would be designed.

PEER-REVIEWER HIGHLIGHTS

Reviewers: N. O'Brien and M. Sheppard

The paper described the differences, both subtle and significant, between monitoring programs in the different provinces, emphasising that a "one size fits all" approach for sea lice monitoring would not work nationally. Reviewers recommended that global glossary or best practices framework for sea lice monitoring be put forward rather than prescribing a program for each province or region within a province.

Clearly stating the objective of the monitoring program is essential - is it just to report sea lice numbers? To follow effects of treatment? For early detection of sea lice? etc. In addition, ongoing evaluation of the effectiveness of monitoring programs should be conducted.

Specific comments were provided on format and context, and on approaches to monitoring. It was indicated the paper was somewhat redundant in repeating each section for each province and that this could be overcome by combining common practices and then highlighting differences among provinces.

The advantages and disadvantages of "prevalence-based" sampling were discussed - this depends on being able to count number of lice per fish rather than total lice from a sample of fish.

GENERAL DISCUSSION HIGHLIGHTS

There was consensus that although the paper presented a good outline of what currently exists, there should be a summary of recommendations for best approaches to monitoring, and references regarding the programs in place. Objectives of each coast's monitoring programs should also be included. It would then be helpful to critically evaluate how the current programs meet the objectives but also, how can they be improved upon, considering how other countries are conducting their monitoring programs. There should also be more context and recommendation around data management, and how to best use this in evaluations of monitoring programs.

Data generated from on farm monitoring programs belong to industry and are considered sensitive, so only data necessary to a particular program should be collected and reported on.

Reporting and dissemination activities must take into account the private and sensitive nature of the information.

WORKING PAPER E.
MONITORING FOR SEA LICE ON WILD SALMON IN WESTERN AND EASTERN CANADA

PRESENTATION HIGHLIGHTS

Presenter: S. Johnson, Co-author (Authors: S. Johnson and S. Jones)

This paper focused on assessing the knowledge needed to design a sea lice monitoring program for wild fish. General considerations, potential risks, the extent of bi-directional interactions between farmed and wild fish, and the impacts of these were considered. Specifically, the paper addressed program design considerations, biology of the host species, oceanographic considerations, current sampling methods and protocols, and data sharing potential in assessing requirements for successful monitoring programs.

The key summary points of the paper were:

- Surveys of sea lice on wild fish have been conducted in response to a lack of information on:
  - the impacts of sea lice on wild salmon at the individual and population levels, including the role that sea lice may play as regulators of wild salmon populations
  - the risks associated with salmon farms as sources of sea lice infecting wild salmon
  - the effectiveness of sea lice management strategies for reducing risks to wild fish
- Majority of surveys of sea lice on wild salmon have been undertaken in British Columbia in two ecologically distinct coastal regions:
  - Broughton Archipelago: *Lepeophtheirus* dominant
  - Strait of Georgia: *Caligus* dominant
- Relatively few such surveys have been conducted on the east coast of Canada.
- Limitations of gear and methods used in sea lice surveys are understood but often not properly communicated nor considered when discussing results.
- The BC Salmon Forum developed exhaustive protocols for conducting surveys for sea lice on wild populations, which should be used in designing surveys - although these are currently out of print, they were reproduced in the Working Paper.

To fully understand the health of wild salmon at the individual and population levels, sea lice should not be the sole focus of field programs - these should be conducted in the context of overall fish health. Laboratory studies are still needed to put into perspective what the levels of sea lice on wild fish mean.

PEER-REVIEWER HIGHLIGHTS

Reviewers: B. Finstad and M. Krkosek

The reviewers provided general comments on the layout and completeness of the document, noting formatting issues and missing citations. B. Finstad's review (Appendix 5) was read into record by Jay Parsons.

It was suggested that the paper could have been more quantitative, but it generally provides broad information on methods; in particular there was a good overview of the monitoring that has been done in the past. There was also room for improvement with respect to information on background sea lice levels. Assessing the effectiveness of sea lice management strategies on

the lice burden of wild fishes could have been dealt with in more detail, for example, giving more information on the criteria to meet the objective. The details on how sampling of wild salmon would be implemented, including details on gear used for sampling, should be outlined, as well as how one might connect data from wild surveys to that collected on farms. It should be noted that although wild surveys are difficult, they provide important information when gathered over years. Several additional surveys to be added to the review were noted.

It was noted that survey design depends on the objective(s) of the survey, which should be clearly stated at the outset.

GENERAL DISCUSSION HIGHLIGHTS

Having a baseline or reference site (without farms) and tracking trends over time is another possible approach to monitoring, however, it is difficult to find "control" sites without farm influence. Natural variability and fluctuations in environmental factors also make results from this approach difficult to interpret.

The use of "sentinel" fish (uninfected fish in artificial enclosures) to monitor sea lice infestations in the wild was also suggested.

Another potential approach would be to utilize the wealth of oceanographic data already available, integrating these data with monitoring data collected over time. However, this might be difficult to do in similar manners on both coasts. There was some subsequent discussion about how to set sea lice count thresholds for treatment, specific to particular areas. There is likely not a single threshold that fits across the entire country, or even across any one province.

With respect to wild Atlantic salmon, sampling for sea lice impacts may be complicated by the very low abundance levels and the SARA protections afforded to some populations. This issue may not be adequately covered in the paper. Non-invasive sampling procedures and gear types are available for collecting data from wild salmon from populations at low abundance.

Monitoring sea lice at counting stations for Atlantic salmon is feasible and has been done in the past. Another option for monitoring wild salmon would be to look at damage caused by sea lice on fish in freshwater. Historically, in the Fraser River, British Columbia, wounds and scar reports were made in observing salmon migrating up the rivers.

WORKING PAPER F.
NON-CHEMICAL MEASURES OF CONTROL AND PREVENTION OF SEA LICE

PRESENTATION HIGHLIGHTS

Presenter: S. St. Hilaire, Co-author (Authors: S. St-Hilaire, S. Robinson, B. Glebe and R. Cox)

This paper presented an overview of key concepts and strategies currently utilized in the non-chemical control and prevention of sea lice infestations, which are supported by research and/or sound biological principles or may still be experimental in nature. The paper also assessed control and prevention measures involving the host directly and provided suggestions on means of decreasing the host susceptibility to sea lice. Means of controlling host susceptibility include reducing stress, increasing resistance through vaccines, and selective breeding. Reducing the potential for infections is another important avenue, for example reducing the potential effect of neighbouring farms on sea lice abundance by assessing current direction in farm placement and distancing farms appropriately. Other strategies in siting farms to aid in sea lice control could include establishing an effective fallowing strategy, decreasing the number of fish on farms, and avoiding wild salmon migration routes.

Non-chemical control methods which might be used to decrease the number of sea lice directly, include sea lice traps, integrated multi-trophic aquaculture (IMTA) and use of cleaner fish such

as wrasses. These are generally untested at commercial scale in Canada, and more work is required on the effectiveness and applicability of these methods and the intensity of scale which would be required in using them to significantly impact sea lice numbers.

Key conclusions from this paper were:

- Non-chemical control of sea lice should be used as part of an integrated sea lice management plan to help reduce the use of therapeutants.

Strategies known to help reduce sea lice include:

- Decrease the concentration of the infective stage of sea lice:
  - Reduce the number of fish hosts on farms and in bay management areas.
  - Increase the distance between farms.
- Manage neighboring farms as a single unit:
  - Fallowing, coordinated chemical treatments, etc.
- Use strategies to maximize water flows on farms to dilute concentration of copepodids
  - Siting, clean nets, etc.
- Increase host resistance to sea lice infection:
  - Reduce stress related immunosuppression.
    - Improve upon or increase the use of good husbandry practices.

PEER-REVIEWER HIGHLIGHTS

Reviewers: L. Hammel and M. Fast

A number of comments were provided, a general theme being the need for more specific references on key points. The title of the paper should include "on salmon farms" to ensure that results are not taken out of context. Early in the document, a statement should be made that the objective of many of the methods discussed is to reduce or eliminate use of chemical treatments. Additional strategies could be added, including some consideration for land based facilities. Also, a discussion about how multiple strategies may interact, and where there may be gaps in research knowledge, would be useful. It was also suggested that a section be added on lice development rates and interaction with hydrographic conditions and currents, which would link well to papers A and B.

It was suggested that a section be included to discuss factors which could promote reduction of sea lice infestations. Elements such as location in the water column could then be discussed.

It was noted that the paper lacked specifics on the various non-chemical treatments. For example, the section on Integrated Multi-trophic Aquaculture lacked substantiation. Advice was also provided on where the paper could benefit on additional, more up to date references, particularly concerning immunostimulants and vaccines.

With regard to which life stages of sea lice should be targeted, the paper would benefit from differentiating between species of sea lice, and from clarifying the importance of targeting all stages of sea lice, not just gravid females. There could also be more specific details about bay management area use in Canada and about semio-chemicals. It was suggested that "stress" was an inappropriate term to use in describing susceptibility of fish to sea lice, and the importance of reducing this should be better justified. The concept of "disease" should be included and defined in the approaches when discussing susceptibility to infection.

The authors accepted the reviewers' comments and committed to addressing them in the paper. There was concern expressed by the authors over the comment to separate out references to the species of sea lice pertinent to the discussion. However, the reviewers noted that there are

differences between the lice life stages, by species, that may impact their response to treatments, such as fallowing. At a minimum, if there would be a difference among species, it should be noted up front in the paper.

Many of the recommended approaches would increase farm costs, so it was suggested that the paper might benefit from some discussion of the economics of using particular treatments; however, this is not the focus of the current science advisory process.

GENERAL DISCUSSION HIGHLIGHTS

There was agreement that the reviews provided were thorough. However, some concern was expressed that several of the management practices noted may not be a viable means of treatment for all farms. For example, siting is listed as a means of control for sea lice, and although management does have siting criteria, it would be currently very difficult for already established sites to move, as new siting is limited. Also, suggestions such as site distancing would need to be tested further before making recommendations for use. The environments in which salmon are farmed in Canada differ by location, and management practices related to siting would need to be tailored to site characteristics, in order to relate to the examples from Chile provided in the paper, with respect to describing neighbouring farm effect on sea lice numbers. If the data are available to do a similar analysis with siting in Canada, they should be provided. If they are not available, this could be identified and challenges in collecting this information (on neighbour effects) could be identified. These points were accepted by the authors.

General discussion continued on the issues which might exist in Canada with building a better analysis of alternate control methods. Interactions between farms, in New Brunswick, are more subtle and complex than elsewhere and it may be difficult to get answers. British Columbia may be the better candidate for this type of work.

Regarding the format of the paper, it was suggested that the various suggested methods for treatment could be listed, followed by what aspects of sea lice biology are being addressed by each, what the treatment is doing in respect to that aspect, and under what environmental conditions these treatments would be appropriate. This would help link this section back to papers A and B.

It was noted that the degree of certainty or uncertainty on the various points in the paper should be characterised, since some of the approaches covered are some way from being implemented. A short term toolbox for the farm is needed, plus some ideas on long-term research priorities. It was noted that the description of relationships between the approaches described in the paper was particularly interesting, supporting an integrated pest management approach.

The discussion closed with agreement from the group that it is important within this paper to reflect that some options may not be possible or practical to implement, but they should still be included, and that research gaps must be indicated.

CONCLUDING DISCUSSION

Following the discussion on the papers, the Co-chairs reviewed the process of developing the Science Advisory Report (SAR). Selected working paper authors were asked to draft sections of the SAR, based on the discussions of the working papers over the past two days. These drafts were the focus for discussions over the third day of the workshop (September 27th), and as a starting point for the development of the SAR. As such, the SAR represents the result of discussions on the third day.

APPENDIX 1: LIST OF PARTICIPANTS

DFO CSAS Sea Lice Monitoring and Non-Chemical Treatment Methods Process

Date: September 25-27, 2012
Location: Delta City Centre, 101 Lyon St. Ottawa, ON K1R 5T9

#	Name	Affiliation
1	Beattie, Mike	NB Department of Agriculture, Aquaculture and Fisheries (DAAF)
2	Brewer-Dalton, Kathy	NB Department of Agriculture, Aquaculture and Fisheries (DAAF)
3	Busby, Corina	DFO - Aquaculture Science Branch (ASB), NCR
4	Carr, Jonathan	Atlantic Salmon Federation (ASF)
5	Chamberlain, Jon	DFO - Aquaculture Management Directorate, Pacific Region
6	Chang, Blythe	DFO Science, Maritimes
7	Chaput, Gerard	DFO Science, Gulf Region
8	Cline, Jeff	DFO - Aquaculture Management Directorate (AMD), Maritimes
9	Fast, Mark	AVC, University of Prince Edward Island (UPEI)
10	Ford, Sharon	DFO - Aquaculture Management Directorate (AMD), NCR
11	Foreman, Mike	DFO Science, Pacific Region
12	Gilbert, Eric	DFO - Aquaculture Operations Management Directorate NCR
13	Glebe, Brian	DFO - Science, Maritimes Region
14	Goodfellow, Danielle	Aquaculture Association of Nova Scotia
15	Greenberg, Dave	DFO - Science, Maritimes Region
16	Hammell, Larry	AVC, University of Prince Edward Island (UPEI)
17	House, Betty	Atlantic Canada Fish Farmers Association
18	House, Nancy	DFO - Aquaculture Science Branch (ASB), NCR
19	Johnson, Stewart	DFO - Science, Pacific Region
20	Jones, Simon	DFO - Science, Pacific Region
21	Keith, Ian	DFO - Science, Pacific Region
22	Kristmanson, Jim	DFO - Science, NCR
23	Krkosek, Marty	University of Otago, NZ (currently University of Toronto)
24	Lane, David	T. Buck Suzuki Environmental Foundation
25	Mabrouk, Gehan	DFO - Science, NL Region
26	Morrison, Diane	Marine Harvest
27	Murray, Harry	DFO - Science , NL Region
28	O'Brien, Nicole	NL DFA Aquaculture Veterinarian/Epidemiologist
29	Page, Fred	DFO - Science, Maritimes Region
30	Parker, Mia	DFO - Aquaculture Management Directorate (AMD), NCR
31	Parker, Pam	Atlantic Canada Fish Farmers Association
32	Parsons, Jay	co-chair, DFO - Aquaculture Science Branch (ASB), NCR
33	Perry, Geoff	DFO - Aquaculture Management Directorate (AMD), NL Region
34	Power, Joanne	DFO - Aquaculture Science Branch (ASB), NCR
35	Powles, Howard	Chair - Ottawa
36	Ratsimandresy, Andry	DFO - Science, NL Region
37	Revie, Crawford	AVC, University of Prince Edward Island (UPEI)
38	Robinson, Shawn	DFO – Science, Maritimes Region
39	Smith, Darlene	DFO - Canadian Science Advisory Secretariat (CSAS), NCR

#	Name	Affiliation
40	St. Hilaire, Sophie	Atlantic Veterinary College (AVC),University of Prince Edward Island (UPEI)
41	Taccogna, Gary	DFO - Aquaculture Management Directorate, Pacific Region
42	Trager, Diane	DFO - Regional Aquaculture Coordinator, Pacific Region
43	Webster, Cindy	DFO – RACO, Maritimes Region
44	Werring, John	David Suzuki Foundation
45	Whelan, Daryl	NL - Department of Fisheries and Aquaculture (DFA)

Teleconference

#	Name	Affiliation
1	Abbott, Matt	NB Conservation Council
2	Dedominicus, Sharon	Marine Harvest Canada
3	Ryan, Teresa	University of British Columbia (UBC)
4	Saksida, Sonja	BC Centre for Aquatic Health Sciences (CAHS)
5	Recchia, Maria	Fundy North Fishermen's Association

APPENDIX 2: AGENDA

Day 1 – Tuesday, September 25, 2012

Time	Agenda Item	Presenter
8:00 – 8:15	Welcome and Introduction	
8:15 – 8:25	Review Agenda, Housekeeping and CSAS Overview and Meeting Procedures	Howard Powles / Jay Parsons
8:25 – 8:50	Review Terms of Reference	Jay Parsons
8:50 – 9:20	Presentation of Working Paper – **A. Biology of *Lepeophtheirus salmonis* and *Caligus spp.* in western and eastern Canada**	Simon Jones and Stewart Johnson
9:20 – 10:20	Reviewer Presentations and Author Response	Karin Boxaspen Mike Beattie
10:20 – 10:35	*Health Break*	
10:35 – 11:35	Open Discussion	
11:35 – 12:05	Presentation of Working Paper – **B. Salmon aquaculture in western and eastern Canada**	Kathy Brewer-Dalton, Fred Page, Peter Chandler and Andry Ratsimandresy
12:05 – 1:05	*Lunch (on own)*	
1:05 – 2:05	Reviewer Presentations an Author Response	Mike Foreman Dave Greenberg
2:05 – 3:05	Open Discussion	
3:05 - 3:20	*Health Break*	
3:20 – 3:50	Presentation of Working Paper - **C. Population ecology and epidemiology of sea lice in Canadian waters**	Sonja Saksida, Ian Bricknell, Shawn Robinson, and Simon Jones
3:50 – 4:50	Reviewer Presentations and Author Response	Larry Hammel, Crawford Revie
4:50 – 5:00	**Day 1 – Summary and Adjournment**	

Day 2 – Wednesday, September 26, 2012

Time	Agenda Item	Presenter
8:00 – 9:00	Open Discussion (Population ecology and epidemiology of sea lice in Canadian waters)	
9:00 – 9:30	Presentation of Working Paper **F. Non-chemical measures of control and prevention**	Sophie St-Hilaire, Shawn Robinson, Brian Glebe, and Ruth Cox
9:30 – 10:30	Reviewer Presentations and Author Response	
10:30 – 10:45	*Health Break*	
10:45 – 11:45	Open Discussion	
11:45 – 12:15	Presentation of Working Paper **E. Monitoring for sea lice on wild salmon in western and eastern Canada**	Simon Jones and Stewart Johnson
12:15 – 1:15	*Lunch (on-own)*	
1:15 – 2:15	Reviewer Presentations and Author Response	
2:15 – 3:15	Open Discussion	
3:15 – 3:30	*Health Break*	
3:30 – 4:00	Presentation of Working Paper - **D. Monitoring for sea lice on farmed salmon in western and eastern Canada**	Sonja Saksida, Daryl Whelan, Mike Beattie, Mike Szemerda and Ian Keith
4:00 – 5:00	Reviewer Presentations and Author Response	
5:00 – 5:10	**Day 2 Summary and Adjournment**	

Day 3 –Thursday, September 27, 2012

Time	Agenda Item	Presenter
8:30 – 9:30	Open Discussion	
9:30 – 10:00	Presentation of Working Paper **G. Summary of advice and recommendations**	Simon Jones and Stewart Johnson
10:00 – 10:15	*Health Break*	
10:15 – 11:15	Open Discussion	
11:15 – 12:15	**Science Advisory Report Discussion and Drafting**	
12:15 – 1:15	*Lunch (on-own)*	
1:15 – 5:00	**Science Advisory Report Discussion and Drafting *(continued)***	

APPENDIX 3: TERMS OF REFERENCE

SEA LICE MONITORING AND NON-CHEMICAL MEASURES

National Peer Review – National Capital Region

September 25-27, 2012
Ottawa, Ontario

Chairperson: Howard Powles

Context

The management of sea lice is a major challenge for the salmon aquaculture industry, both nationally and internationally. It is recognized that there are biophysical differences between salmon growing regions within Canada including species of sea lice, alternate hosts, oceanography, etc. These differences will be considered and addressed within the peer review process.

Fisheries and Oceans Canada (DFO) Aquaculture Management Directorate has requested science advice to support the optimization of sea lice management, including the development of integrated pest management and mitigation strategies, and science-based conditions of licence.

To date, there have been many studies regarding various aspects of sea lice biology, monitoring control and management, as such, it is important to consolidate the large body of work in order to provide managers with peer reviewed, robust science advice. This advice is required to support management decisions on issues such as thresholds/triggers, effective monitoring protocols, and wild/cultured interactions related to sea lice.

Objective

There is a need to assess the state of knowledge informing sea lice management measures, monitoring and interactions between cultured and wild fish and provide scientific advice to inform management practices. Working paper(s) will examine issues on both the East and West coasts of Canada including commonalities and differences (e.g., species of sea lice, alternate hosts, oceanography) between the different salmon growing regions.

The scientific review will be structured and developed to address questions in the following areas:

Population ecology and epidemiology of sea lice in Canadian waters

1. Role of other sea lice hosts (wild salmonid and non-salmonid) as reservoirs and other factors influencing sea lice dynamics near or on farms.
2. Scientific basis for setting management and regulatory thresholds to treat farm salmon and minimize the risk of harm to wild juvenile salmon from exposure to farm-source sea lice.

Monitoring for sea lice on farmed and wild salmon in western and eastern Canada and advice on sound methodologies

3. Sampling design protocols for **on-farm** lice monitoring, including: number of fish to be sampled, identification of lice, number of samples, handling of fish, etc.
4. Program design for **on-farm** lice monitoring, including: frequency of sampling, timing, environmental factors to be considered, sea lice dynamics, etc.

5. Sampling design protocol for **wild fish** lice monitoring, including: number of fish to be sampled, identification of lice, number of samples, handling of fish, background sea lice levels, etc.
6. Program design for **wild fish** lice monitoring, including: frequency of sampling, out-migrations, in-migrations, sampling location, timing, environmental factors to be considered, sea lice dynamics, and other considerations (e.g., species differences, at-risk status of wild stocks of interest), etc.
7. Protocols for the management, dissemination and analysis of data resulting from monitoring programs.

Non-chemical measures of control, and prevention

8. Scientific advice on factors that influence the effectiveness of fallowing as a means of sea lice control, including fallowing time required, scale of fallow (e.g., farm-scale versus bay-scale), other factors required to interrupt sea lice population dynamics on farms to decrease next year's load, etc.
9. The effect of farm density and stocking density on sea lice population dynamics at different scales (i.e., individual pens, individual farms, within a bay or area).
10. Scientific evidence to the effectiveness of other means of sea lice control such as, but not limited to, sea lice traps, cleaner fish, IMTA (biological filtering), etc.

Expected Publications

- Science Advisory Report
- Research Document(s)
- Proceedings

Participation

- DFOAquaculture Science Branch, Ecosystems and Oceans Science, Aquaculture Management Directorate;
- Provinces;
- Academia;
- Aquaculture industry;
- First Nations;
- Wild fishery organizations; and
- Environmental non-governmental organizations.

APPENDIX 4: REVIEW BY K. KROON BOXASPEN

Review of document CSAS Sea Lice Monitoring Section A: Final Draft

By Karin Kroon Boxaspen

Head of Aquaculture, Research and Advice, Institute of Marine Research, Norway.

I have with interest read the final draft of document: CSAS Sea Lice Monitoring Section A, Biology of *Lepeophtheirus salmonis* and *Caligus* spp. in western and eastern Canada written by Simon Jones and Stewart Johnson of the Pacific Biological Station, Canada. The document is a part of a larger document "Sea lice monitoring and non-chemical measures".

Overall recommendations:

The report is well written and contains a brief but succinct and well documented review of several key issues concerning the biology of several sea lice species that are relevant in relation to international aquaculture of salmonids and the Canadian situation in particular. The scope of the review is fitting the overall document and the chosen references are up to date including central older articles and also newly published articles.

I have made no changes to the document and recommend that it is accepted as is.

The authors of the report

The authors are both major contributors to the overall volume of international publications in sea lice biology. They are in my view both part of a hand full of top international experts that are well known and recognised in the world of sea lice research and thus Canada is lucky to have this level of competence "in house".

The report:

The report focuses on the biology of several sea lice species including *Lepeophtheirus salmonis* and several *Caligus* spp. This is fitting since Canada has a slightly different challenge compared to other salmon producing countries with coasts and salmon production in two oceans. The European salmon producing countries are only in the Atlantic Ocean and only two species of sea lice have been described as a major problem so far (*L. salmonis and C. elongatus*).

Areas covered:

All the areas covered such as geographic variation, life cycle, reproductive output, effects of temperature and salinity, sensory adaptation and host factors including scope for vaccination are highly relevant for being able to describe sea lice infections and the possible distribution of the parasites in question.

Future research points:

The report points out the limits to our knowledge and the way forward for new areas of research.

There is a list of non–prioritised aspects for future research on both groups of sea lice at the end of the report. This list closely corresponds with other lists that have been made over the last years in other settings.

The two first points in the list for *L. salmonis* were for instance also tagged as the most important in an international project sponsored by the Norwegian Research Council a few years back (Comparelice). Since *Caligus* spp. is less known in the scientific literature it is fitting that the list is more basic in approach.

Reference list:

A very simple search in web of science on sea lice restricting it to salmon produces over 500 hits. Thus a more extensive list of references could have been included but the present reference list covers the topics treated in similar manner and includes a few well chosen references for each topic.

21 September 2012

Karin Kroon Boxaspen

APPENDIX 5: REVIEW BY B. FINSTAD

Review of Sea lice monitoring and non-chemical measures Section E
Monitoring for sea lice on wild salmon in western and eastern Canada

By: Bengt Finstad

Norwegian Institute for Nature Research, P.O. Box 5685 Sluppen, N-7485 Trondheim, Norway.

Email: bengt.finstad@nina.no

General Comments:

Unfortunately I could not attend the meeting in Ottawa October 25-27 due to other obligations in Norway but I hope this review can be of some help for this process. I will be able to participate on site in this process next time, if needed.

There are a lot of new reports/reviews of salmon lice monitoring including tolerance limits and methods for monitoring on wild fish (Sea trout, Atlantic salmon and Arctic charr) in Norway – examples here are Taranger et al. (2010, 2011, 2012); Finstad et al. (2010); Finstad & Bjørn (2011); Bjørn et al. (2011ab), Anon (2011, 2012). Most of these reports are unfortunately in Norwegian but sections here should be possible to translate for further use.

Additional References:

Anon. 2011a. Status for norske laksebestander i 2011. Rapport fra Vitenskapelig råd for lakseforvaltning. nr 3, 285 s.

Anon. 2012. Lakselus og effekter på vill laksefisk – fra individuell respons til bestandseffekter. Temarapport fra Vitenskapelig råd for lakseforvaltning. nr 3, 56 s.

Berg, M., Finstad, B., Kvalvik, A., Uglem, I., Bjørn, P.A. & Nilsen, R. 2012. Laksefisk og luseovervåking i Romsdalsfjorden. NINA Rapport 779: 1-43.

Bjørn, P.A., Finstad, B., Asplin, L., Skilbrei, O., Nilsen, R., Serra Llinares, R.M. & Boxaspen, K.K. 2011a. Metodeutvikling for overvåkning og telling av lakselus på viltlevende laksefisk. Rapport fra havforskningen nr. 8-2011, 1-52.

Bjørn, P.A., Asplin, L., Nilsen, R., Serra Llinares, R.M., Boxaspen, K.K., Finstad, B., Uglem, I., Kålås, S., Barlaup, B. & Wiik Vollset, K. 2011b. Sluttrapport til Mattilsynet over lakselusinfeksjonen på vill laksefisk langs Norskekysten i 2011. Rapport fra havforskningen nr. 19-2011, 1-33.

Finstad, B., Bjørn, P.A., Todd, C.D., Whoriskey, F., Gargan, P.G., Forde, G. & Revie, C. 2010. The effect of sea lice on Atlantic salmon and other salmonid species. I: Atlantic salmon ecology (red. Ø. Aas, S. Einum, A. Klemetsen & J. Skurdal). Wiley-Blackwell, Oxford, UK, s. 253-276.

Finstad, B. & Bjørn, P.A. 2011. Present status and implications of salmon lice on wild salmonids in Norwegian coastal zones. I: Salmon lice: An integrated approach to understanding parasite abundance and distribution (red. S. Jones & R. Beamish). Wiley-Blackwell, Oxford, UK, s. 281-305.

Taranger, G.L., Boxaspen, K.K., Madhun, A.S. & Svåsand, T. 2010. Risikovurdering – miljøvirkninger av norsk fiskeoppdrett. Rapport, Havforskningsinstituttet, Bergen.

Taranger, G.L., Boxaspen, K.K., Madhun, A.S. & Svåsand, T. (red.) 2011. Oppdatering - Risikovurdering – miljøvirkninger av norsk fiskeoppdrett. Rapport, Havforskningsinstituttet, Bergen.

Taranger, G.L., Svåsand, T., Bjørn, P.A., Jansen, P.A., Heuch, P.A., Grøntvedt, R.N., Asplin, L., Skilbrei, O., Glover, K., Skaala, Ø., Wennevik, V. & Boxaspen, K.K. 2012. Forslag til førstegenerasjons målemetode for miljøeffekt (effektindikatorer) med hensyn til genetisk påvirkning fra oppdrettslaks til villaks, og påvirkning av lakselus fra oppdrett på viltlevende laksefiskbestander. Rapport fra Havforskningsinstituttet Nr. 13-2012, Veterinærinstituttets rapportserie Nr. 7-2012, 40 s.

SPECIFIC COMMENTS:

Program Design Considerations:

This is a very important summary giving the limitations for such monitoring programs which are time consuming and expensive and need to be performed over years to analyze trends in the sampling.

Sea lice – Biological, Ecological and Behavioral Differences:

Biological and Ecological Differences

- I agree that it is likely that all species of sea lice show similar general trends with respect to environmental conditions.
- The salinities at which species of sea lice show reduced survival should be at salinities below 20 ppt.
- There are few studies on the differences between species with respect to the ability to tolerate and survive in waters of low salinity.

Behavioural Differences

- It is correct that in general, *Lepeophtheirus salmonis* is less likely to leave its host upon disturbance, when compared to species of *Caligus*.
- With regards to the authors statement: "The ability of all species of sea lice to transfer as preadult and adults between hosts needs to be considered when discussing sea lice stage distribution on wild hosts" – we observe in the field that that *Caligus* are much more able to move between hosts than *Lepeophtheirus*.

Migration Patterns and Rates of Passage of Juvenile Salmon:

Atlantic Salmon

Atlantic salmon migrations are complicated, and duration in fjords vary a lot, as described in Anon 2011 (see references, above) and references therein. In Norway, duration from rivers through fjords to open sea can vary from 5 to up to 40 days exposing the postsmolts to sea lice larvae through the fjord system before the fish enters the sea.

Pacific Salmon

I agree with the authors that it is possible that migration routes and residency times may not be consistent over the period of migration and/or between years.

Oceanographic Conditions

This is important – especially in narrow fjords, oceanographic factors can contribute significant to local infestations of sea lice from farms to wild salmonids.

Use of Oceanographic Models to Aid in Study Design:

British Columbia

Oceanographic conditions have a great influence on sea lice dynamics. Below 20 ppt. we observe lower sea lice load on fish than above 20 ppt. See:

Plantalech Manel-la, N., Thorstad, E.B., Davidsen, J.G., Økland, F., Sivertsgård, R., McKinley, R.S. & Finstad, B. 2009. Vertical movements of Atlantic salmon post-smolts relative to measures of salinity and water temperature during the first phase of the marine migration. Fish. Manage. Ecol., 16: 147-154.

Frequency and Duration of Sampling:

The frequency and duration of sampling is important (although dependent on available budget), given good methods, qualified personnel and that the study/monitoring area has a broad geographical spread. Without these, monitoring will have reduced value.

Other factors that are important when designing the sampling frequency and duration are:

- Hydrography of the fish farms
- Availability of good sea lice counting and fish biomass data from fish farms (you probably need weekly data), in order to calculate the total host population on each farm. Model development is then an outcome of this.

Sample Size:

(pg 17) "...sea lice like many other parasites are unequally distributed in host populations" – this would be a negative binomial distribution.

To avoid underestimating sea lice counts, use live fish sampling (FISH-lift) and bag-nets (where lice can be counted on anaesthetized fish (sea trout) and released after counting – see Berg et al. 2012 (above).

Status of Host Stocks:

Destructive sampling: As mentioned above – live fish sampling is an alternative here. At least we are sampling sea trout in Norway and release them after sea lice counting – but in Canada this might be a technical problem due to other fish species.

Sampling Gear:

See Bjørn et al 2011b and Berg et al. 2012 page 17 for alternative sampling gear. Plankton sampling in free water-masses might also be an alternative method. See also Barlaup et al. 2012. Doi:10.1016.j.fishres.2012.01.024

Sampling protocols and sea lice and juvenile fish identification:

- This chapter should be ranked related to reliable sampling methods and standardized for the whole sampling programme.
- For fixing whole fish in the field, formaldehyde is not recommended – use ethanol instead. We use this on Atlantic salmon postsmolts taken by FISH-lift.
- We analyze the stage of juvenile sea lice on fish freshly caught in the field by use of a hand held lens. Stages: larvae, mobiles, adult males and adult females. This saves a lot of time and gives good in situ results.

Sea Lice Reporting

See above comment in reference to copepodid, chalimus, preadult and adult stages.

Host parameters: methods of measurement and reporting:

Re: examining fish for damage: In Taranger et al. 2012 there is developed tolerance levels and estimated mortality for smolts and larger fish based on laboratory studies on sea trout, Atlantic salmon and Arctic charr. These limits are dynamic and subject to changes when we have performed studies on tolerance limits for wild fish of different size classes.

The ranking system by Beamish et al. (2005c) looks better and easier to use.

Protocols for the management, dissemination and analysis of data resulting from monitoring programs:

Data from fish farms on lice levels and biomass are essential to obtain. Also – population data – historic and present are also important to include in order to analyze "before and after" effects of sea lice.

APPENDIX 6: REVIEW BY M. KRKOSEK

Review of Sea lice monitoring and non-chemical measures Section E
Monitoring for sea lice on wild salmon in western and eastern Canada

Preliminary draft

(pg 5 – author notes and commentary)

Transfer of mobile stages from farmed and wild salmonid and non-salmonid host may explain reports of preadult and adult sea lice on juvenile salmon that have recently entered the marine environment (CITATIONS). As reported in Section ???? *Caligus clemensi* from wild hosts is known to infect Atlantic salmon as preadults and adults (some reference to Sonya's section?).

(pg 27 – reference to unnumbered figures that are not in the paper)

Summarizing the taxonomic keys, in Atlantic waters and adjacent seas, the preadult and adult stages of *C. curtus* and *C. elongatus* can be distinguished from *L. salmonis* by the presence of lunules (Figure ?). Adult *C. curtus* can be distinguished from *C. elongatus* by differences in the shape of the genital complex and abdomen as well as differences in the number of setae on the exopod of the fourth leg (Figures ? and ?).

(pg 17 – missing citations to support statement)

Unfortunately, sea lice like many other parasites are unequally distributed in host populations with some hosts harboring many and most few or none.

Overall Objectives – Terms of Reference

5. Sampling design protocol for **wild fish** lice monitoring, including:

- number of fish to be sampled (yes – could be more quantitative)
- identification of lice (yes – very good)
- number of samples (yes – discussed but vague in relation to objectives)
- handling of fish (yes – very good)
- background sea lice levels, etc. (needs more work)

6. Program design for **wild fish** lice monitoring, including:

- frequency of sampling (yes – discussed but vague wrt objectives)
- out-migrations (yes – discussed)
- in-migrations (no)
- sampling location (yes – but vague wrt objectives)
- timing (yes – knowledge and uncertainty of migration timing)
- environmental factors to be considered (yes – very good)
- sea lice dynamics (vague)
- and other considerations (e.g., species differences, at-risk status of wild stocks of interest), etc. (yes – discussed)

Chapter Objectives

The chapter begins by saying that a well-designed and executed, systematic surveillance program sea lice data from wild fish will:

1. inform decision makers on the occurrence of sea lice on wild juvenile salmon
2. extent of bi-directional interactions of sea lice between wild and farmed salmon
3. effectiveness of sea lice management strategies applied on farms

Objective (3) needs to be clarified as to what objective sea lice management is effective at meeting. Is it productivity of farms or minimizing infections of wild salmon? I agree that these three points provide a good rationale for monitoring sea lice in wild salmon populations that would be of interest to managers.

The section does not assess how monitoring should be designed in order to inform on these points. The required design of a monitoring program to meet these points, differs among the points. In particular, point (1) might need a randomized sampling program of juvenile salmon, point (2) might need data on wild adult salmon to evaluate the wild -> farm interaction, and (3) might need quite specific data from wild fish in relation to their migration past the farms whose management is being evaluated. If a goal of the chapter is how to conduct sea lice monitoring of wild fish to meet these points, there needs to be some attempt to pull together the information and lessons learned from past and ongoing monitoring programs on how to address these points. Such effort would make the chapter more useful to managers so as to give guidance about what needs to be done in order to address the three points above.

The chapter gives an overview of the types of monitoring programs that have been ongoing as well as biological details of lice and salmon that are relevant to considerations of how to monitor. There is an emphasis on variability among monitoring programs, in terms of gear/logistics as well as uncertainty in understanding of biology of salmon and lice. It is an impressive range of monitoring programs and techniques that have been implemented, particularly in BC, and it is useful to see it described in one place (particularly Table 1). I think it would be more useful if there were a further attempt to provide an assessment of what can work well in which situation. For example, it is useful to see the different gear types that have been used among the sampling programs, but which type of gear is optimal for which species and at which life-stage? The chapter falls short of making an overall assessment, which would be more helpful than simple description of what has been done.

(pg 4) I agree that variation in environmental factors should be a consideration when designing a monitoring program. But, in which way? The chapter suggests that areas of low salinity, for example, could be excluded from monitoring programs to save costs and improve efficiency. This seems to make sense based on experimental data from labs that indicate lice do not survive well in low salinity waters. However, it is also my experience that one commonly finds lice on wild juvenile salmon in areas of low salinity. Shouldn't a monitoring program include such areas in order to generate data that are representative of the environmental variability in the systems? And, wouldn't such data be of interest in order to evaluate if predictions from labs are borne out in the field?

(pg 11) Sampling alternate host species may be a worthwhile consideration under some objectives (e.g. improving general understanding) when designing a monitoring program.

(pg 5) Monitoring of lice on farms should also be conducted in careful ways so that the data can be useful for comparing with data from monitoring wild fish. Pg 5 bottom simply says that farm data can be obtained. It might be better to indicate that monitoring of farm data should be also conducted, and done in such a way so as to be comparable with data from farmed fish.

Should monitoring of wild fish include abundance of wild fish? It is alluded that this might be of interest but that it may be problematic because its not suitable for some gear types. Please go on to assess which gear types are possible for this and which are not. That would be more helpful.

(pg 7) "There are limited data on adult distribution and residency times in the Bay of Fundy and data which are available don't have the spatial resolution necessary for planning of field based sampling programs."

Why are the data on adult salmon distribution and residency times in the Bay of Fundy not useful for planning field studies. It says they are too low resolution. Please describe the data and indicate why they are too low resolution. What needs to be done to improve this situation?

Do you need to explain what PARR is? BAMP?

(pg 8) Salmon migrations in the Broughton Archipelago occur through Knight Inlet and Tribune Channel. These are main migration routes. There is no other way for the fish to move through the system.

Monitoring programs missing from the table 2:

- Clayoquot Sound
- Nootka/Muchalet Inlets
- Broughton Archipelago

Pg 11: "Info on distribution, migration, residency time of salmon and non-salmon in near shore BC Atlantic Canada, NFLD lacks sufficient detail to be of much use in planning wild salmon sea lice monitoring programs."

I think that quite a lot is known:

- habitats of juvenile salmon
- migration season
- migration timing

Figures referred to in text do not exist. One figure in document illegible and has no caption.

(pg 30) Protocols for the management, dissemination and analysis of data resulting from monitoring programs.

No discussion of analysis of data, apart from basic descriptive statistics, particularly wrt objectives.

(pg 16) Sample size for getting reliable estimates of sea lice abundance or prevalence rather than finding statistically significant differences.

(pg 24) Assessment of damage to the host can be partitioned between chalimus versus pre-adult/adult stages.

Other salmonid species: Should be considering steelhead and sea-run trout and char?

Structure of headings and subheadings need to be clarified.